

# Improving Performance of Snowmelt Models through use of CERES Radiation Data

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# Need for snow models

- **Snow accumulation and melt critical to water supply, energy production, and flooding in western US.**
- **Historical records no longer accurate predictors.**

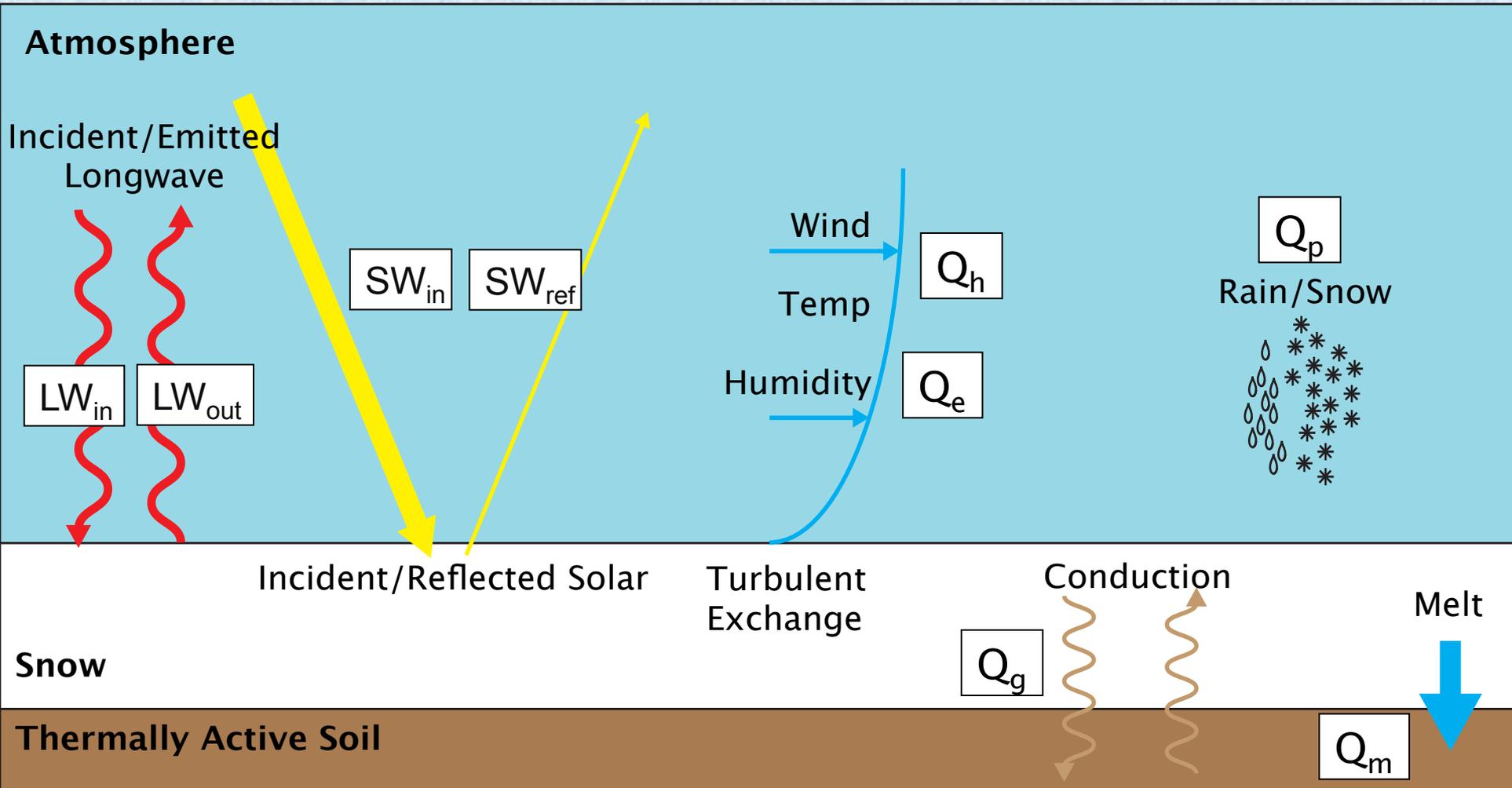
## **Models needed to**

- **improve seasonal forecasting.**
- **improve representation of the hydrological cycle in large-scale models.**
- **determine response of snow processes to global warming.**
- **accurately compute boundary layer feedbacks in climate models.**

# Energy balance snowmelt modeling

Snow amount controlled by precipitation (addition) and energy balance (melting).  
Energy balance dominated by radiation terms.

$$(LW_{in} - LW_{out}) + (SW_{in} - SW_{ref}) + Q_h + Q_e + Q_g + Q_p - dU/dt = Q_m$$



# Model application

## Typical measurements

Snow water equivalent  
2m temperature ( $T_{\max}$ ,  $T_{\min}$ )  
Precipitation

## Additional variables

Wind speed  
Relative humidity  
Radiative fluxes

→ Estimate most energy budget terms

**SW down: Parameterize based on daily  $\Delta T_{\text{air}}$  or solar geometry and transmission**

**LW down: Estimate based on  $T_{\text{air}}$ , RH, cloudiness**

**Albedo: Parameterize based on change in time**

**LW up: Estimate  $T_{\text{sfc}}$**

**Tune model for turbulent fluxes**

# Project description

**Assumption: Using satellite-based surface fluxes instead of simple parameterizations should improve snowmelt modeling results.**

- **Inherently better accuracy**
- **Better capture spatial and temporal variability**

**➔ Replace parameterized fluxes with CERES SYN and MODIS-based (from Rachel Pinker) values.**

**Run both versions of models at selected locations and compare to observations.**

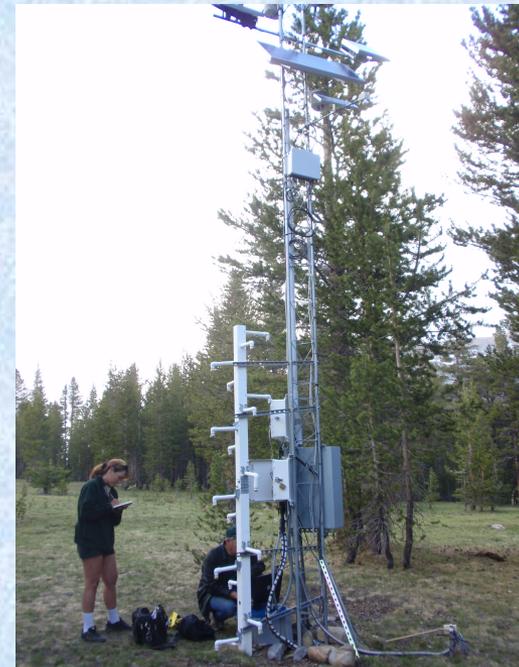
**Potential problem: Model tuning**

# Model evaluation sites

Identifier	Name	State	Geography	Latitude	Longitude	Elev. (m)
CSL	Central Sierra Snow Lab	CA	Sierra Nevada	39.32	-120.37	2100
LOS	Lost Horse	WA	East side of Cascade Range	46.35	-121.07	1561
RME	Reynolds Creek	ID	Owyhee Mountains	43.19	-116.78	2100

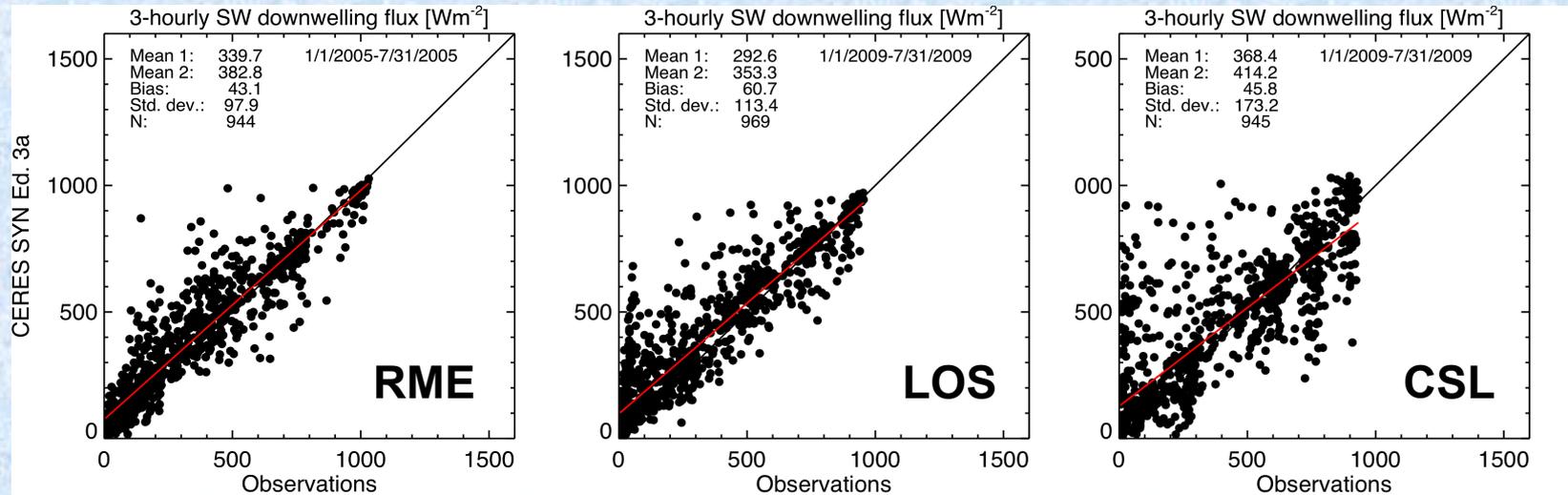


Central Sierra Snow Lab (CA)

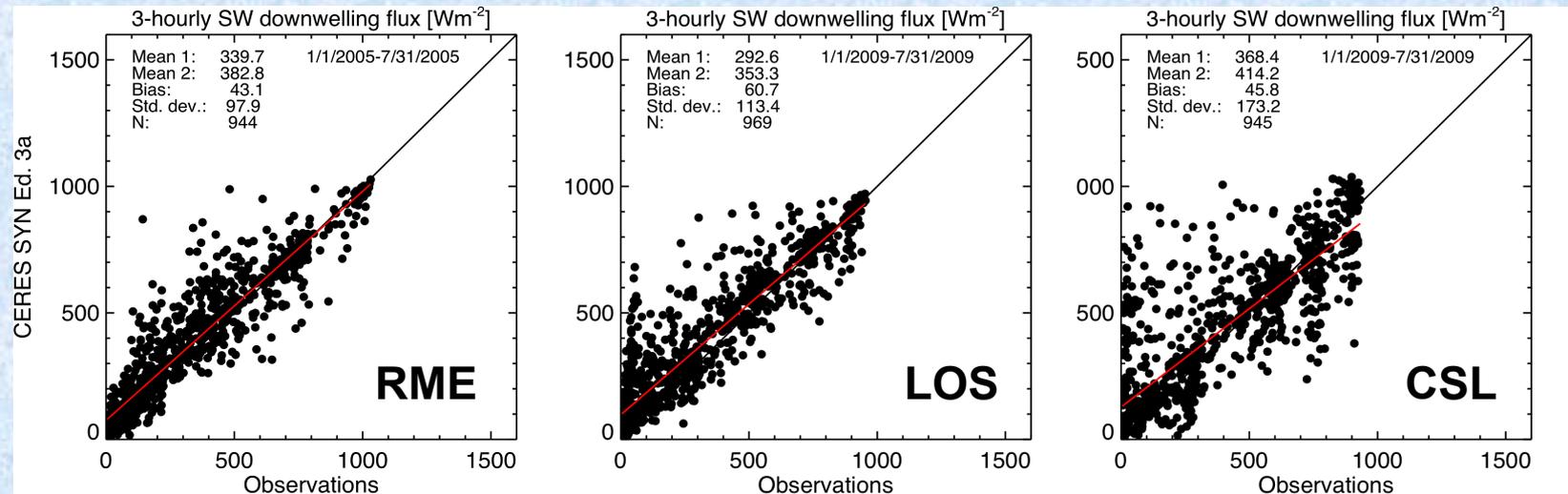


Dana Meadows (CA)

# Evaluation of CERES SYN over mountain sites

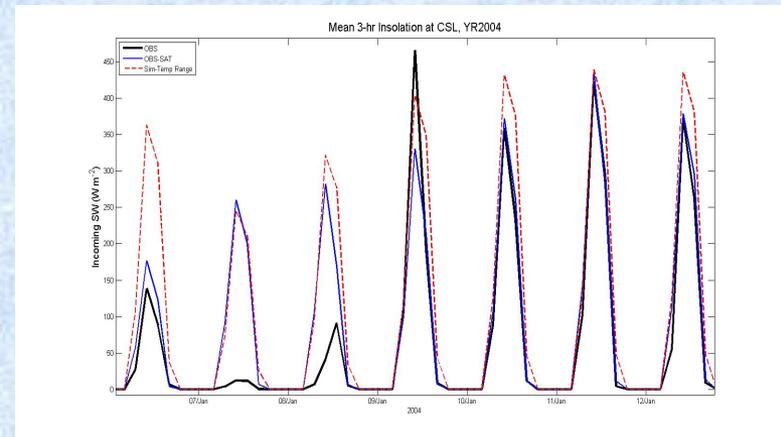


# Evaluation of CERES SYN over mountain sites



## High biases:

- Terrain shadowing of radiometers
- Snow on radiometer dome
- Little maintenance



**CSL, January 2004**

## Evaluation of CERES SYN over mountain sites

Site	Year	CERES SYN Ed. 3a		
		Bias	Std. Dev.	N
CA_DAN	2004	48.2	154.9	1499
	2005	18.5	151.0	913
	2009	44.3	156.9	927
CA_TUM	2004	56.2	119.5	1609
	2005	39.1	127.4	976
CA_CSL	2009	45.8	173.2	945
CO_SASP	2005	38.5	138.3	881
	2009	48.5	151.5	964
ID_RME	2004	44.7	102.6	1553
	2005	43.1	97.9	944
WA_LOS	2009	60.7	113.4	969
	Mean	44.3	135.1	

**Biases: 20-60 Wm<sup>-2</sup>, always positive**

**Std. dev.: 100-170 Wm<sup>-2</sup>**

**Influenced by surface measurement problems**

# Point snowmelt simulations

**Model: Utah Energy Balance**

**SW irradiance:**

- **Observations ★**
- **Empirical model**
- **CERES SYN Ed. 3a**

**Albedo:**

- **USACE – Simple off-line parameterization**
- **BATS – Snow aging routine from Biosphere–Atmosphere Transfer Scheme ★**
- **CERES  $SW_{up}/SW_{dn}$**

**LW irradiance:**

- **Empirical model ★**
- **CERES SYN Ed. 3a**
- **CERES SYN Ed. 3a corrected for elevation (Marty et al., 2002)**

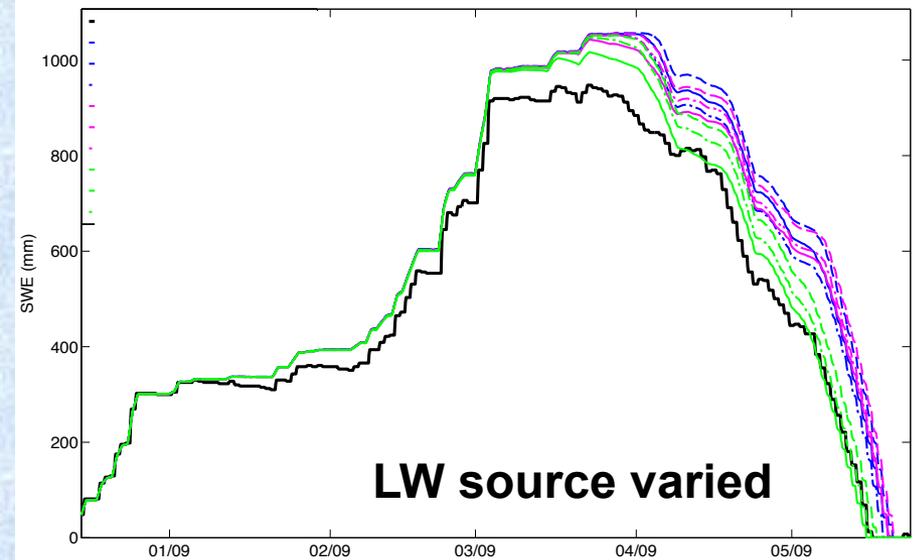
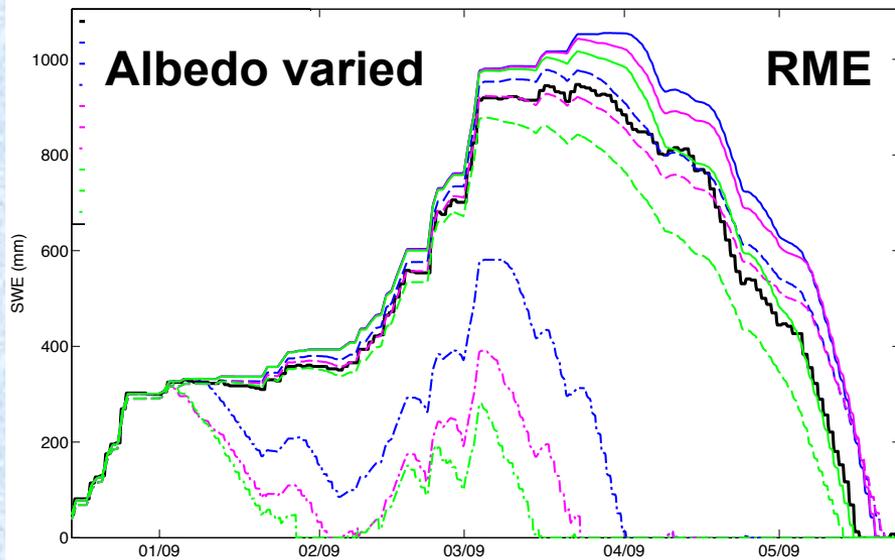
**★ = Used in model tuning.**

# Model performance evaluation

## Modeled vs. measured snow water equivalent (SWE)

- **SWE time series**
- **RMSE of time series**
- **Peak SWE**
- **Snow disappearance date**
- **Average melt rate**

# Results: Full season

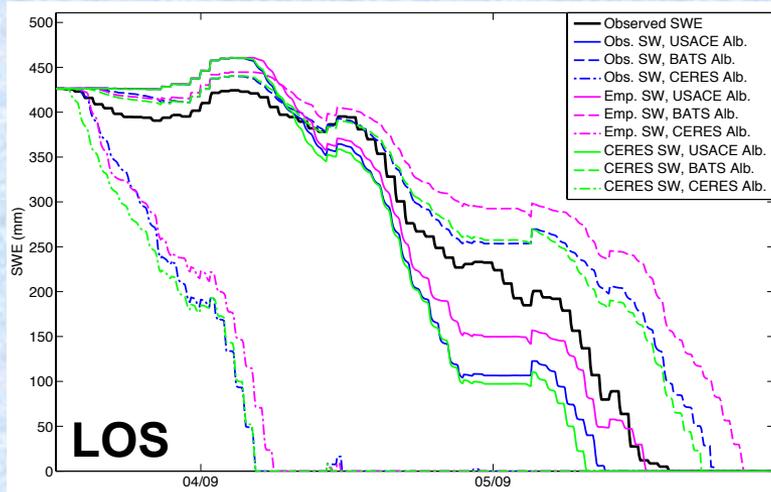
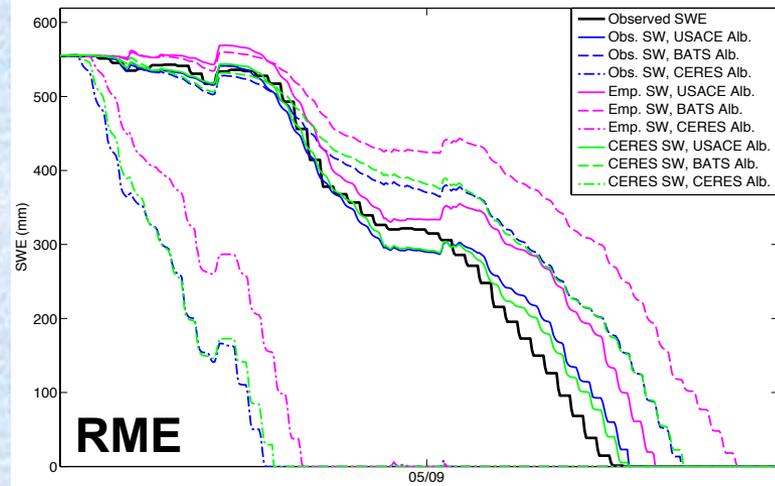
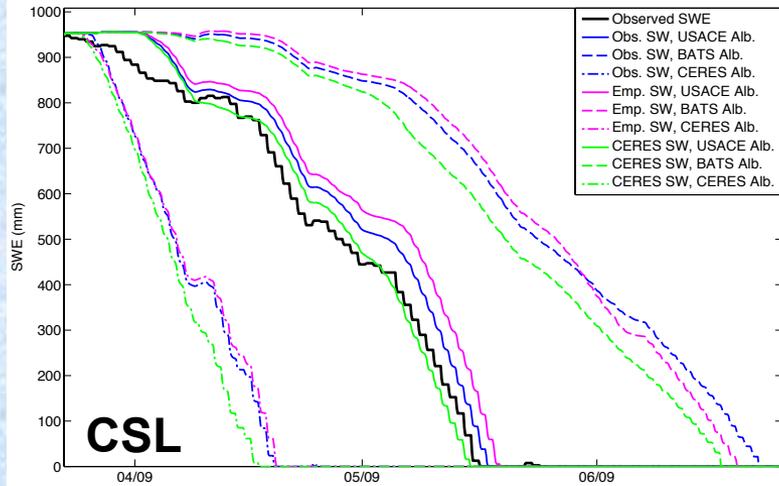


**Compensating errors are common.**

**Evaluation depends on which metric you choose.**

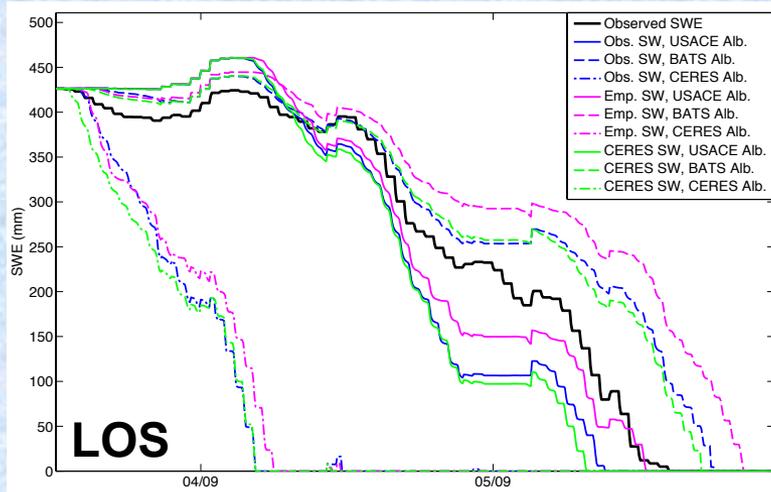
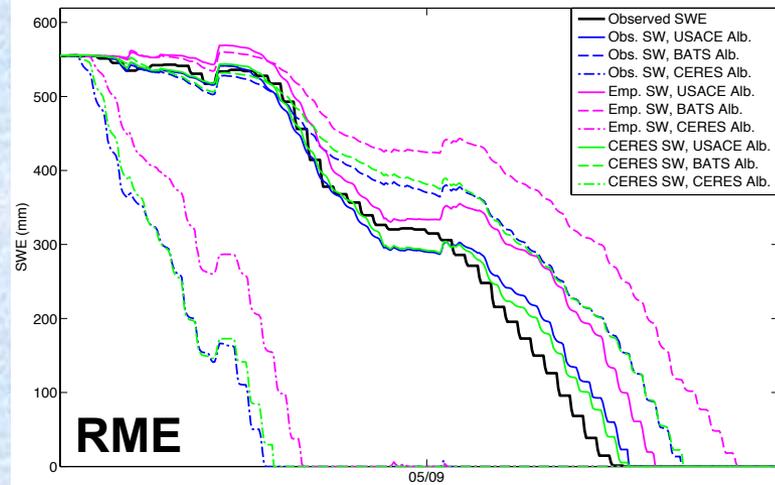
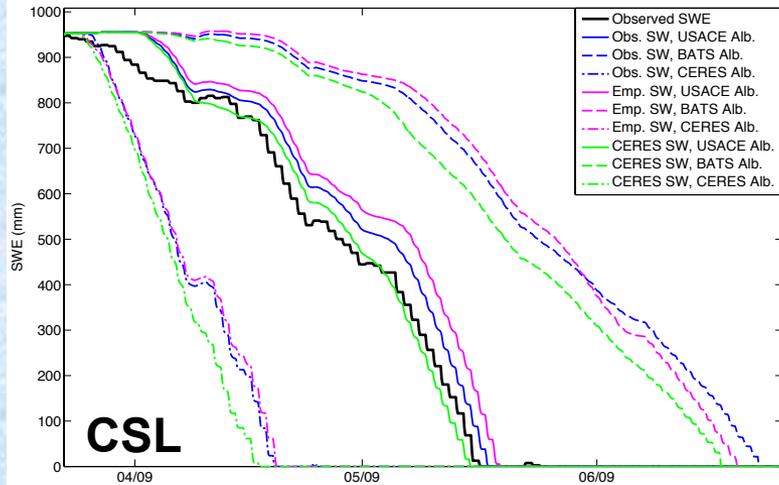
**Differences in irradiance are more important during melt than accumulation season.**

# Results: Melt season – SW



- Observed SWE
- Obs. SW, USACE Alb.
- Obs. SW, BATS Alb.
- Obs. SW, CERES Alb.
- Emp. SW, USACE Alb.
- Emp. SW, BATS Alb.
- Emp. SW, CERES Alb.
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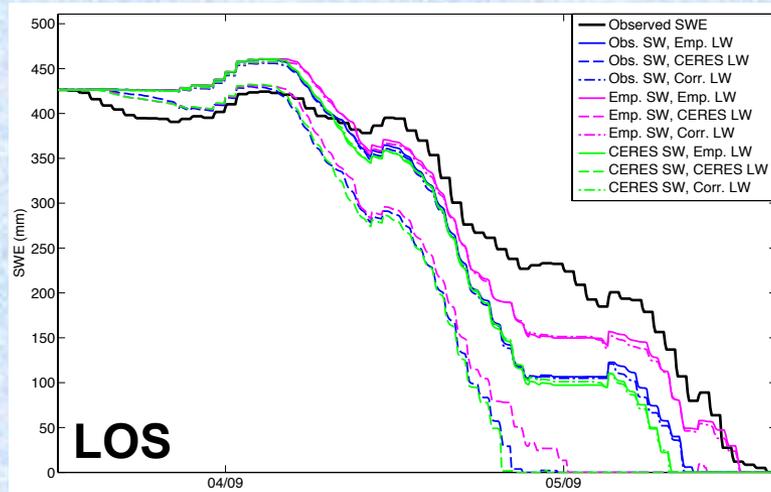
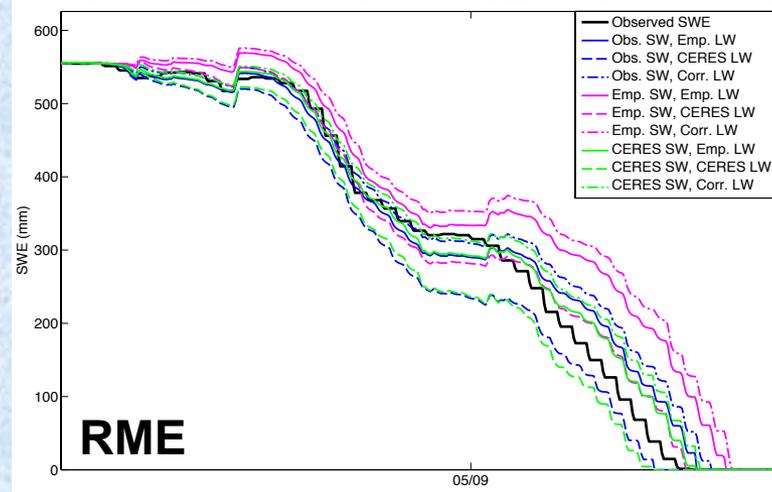
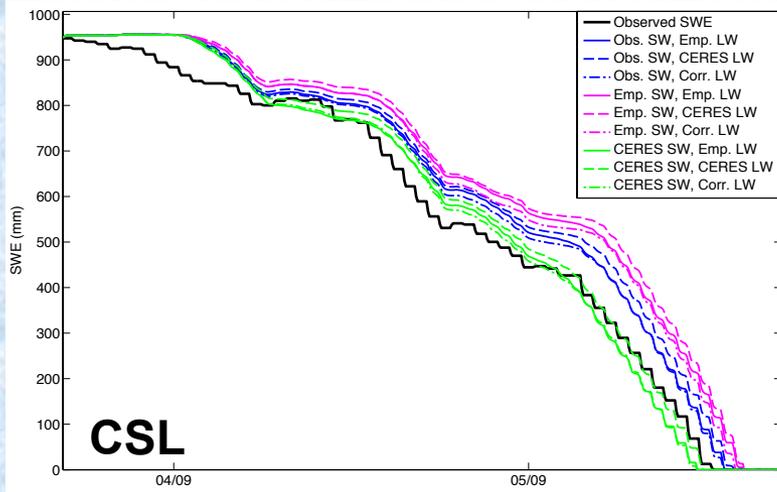
**CERES albedo not representative of sites.**

**Simple off-line albedo parameterization (USACE) works best.**

**CERES SW irradiances highest – yield fastest melt.**

**CERES SW performance as good as obs.**

# Results: Melt season – LW



- Observed SWE
- Obs. SW, Emp. LW
- - Obs. SW, CERES LW
- . - . Obs. SW, Corr. LW
- Emp. SW, Emp. LW
- - Emp. SW, CERES LW
- . - . Emp. SW, Corr. LW
- CERES SW, Emp. LW
- - CERES SW, CERES LW
- . - . CERES SW, Corr. LW

**CERES LW too high;  
improved by elevation  
adjustment.**

**Adjusted CERES LW tends to  
be similar to empirical values.**

**LW irradiances tend to be too  
low.**

**Relative results for CERES  
are mixed – no worse than  
others.**

# Distributed snowmelt simulations

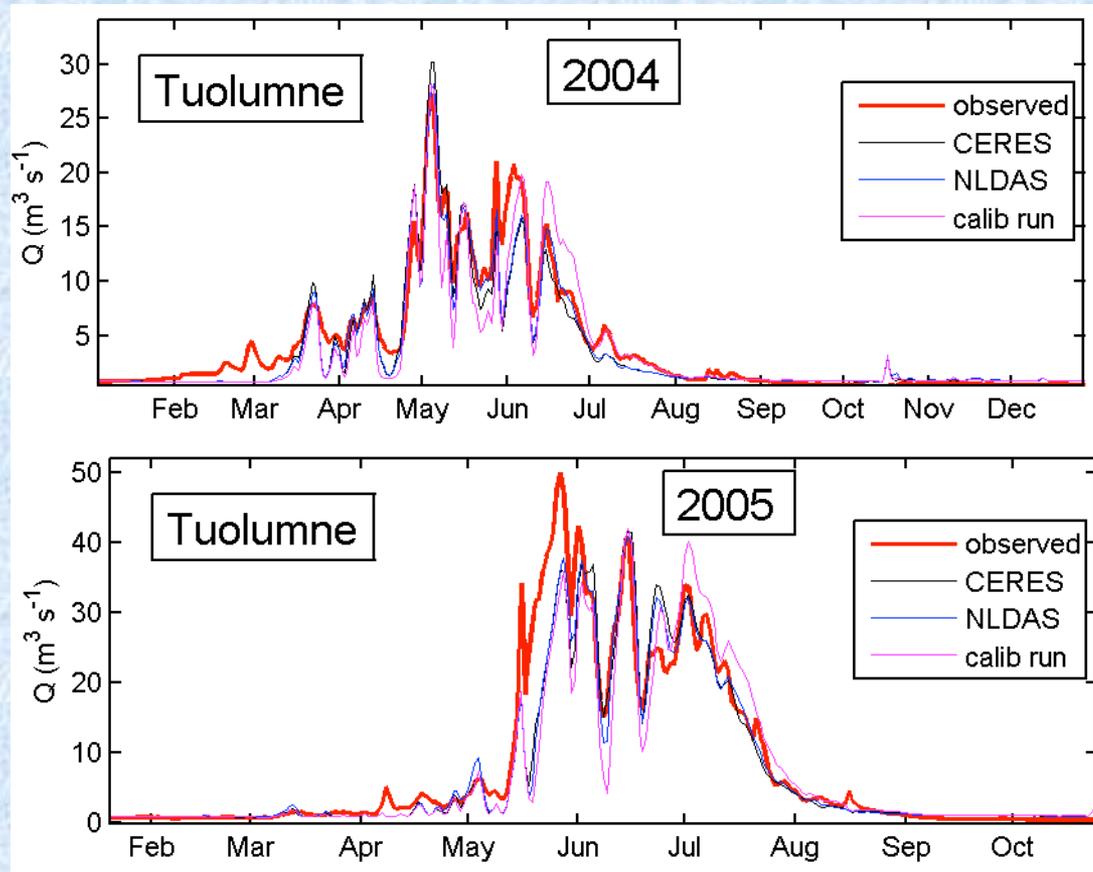
**Simulate snow melt over Tuolumne Basin over 2004 and 2005 using DHSVM.**

**Apply four different shortwave forcing time series:**

- **Observations**
- **Parameterization ★**
- **CERES SYN Ed. 3a**
- **NLDAS (North American Land Data Assimilation System)**

**Compare modeled snow amount to measured stream flow.**

# Distributed snow simulation results



**CERES and NLDAS SW irradiances produce better results than parameterization does.**

# Conclusions

**Evaluation:**

**SW biases: +20-60 Wm<sup>-2</sup>; std. dev.: 100-170 Wm<sup>-2</sup>**

**Influenced by surface measurement problems**

**SW irradiance:**

**CERES albedo not representative of sites.**

**CERES SW irradiances highest – yield fastest melt.**

**CERES SW performance as good as obs.**

**LW irradiance:**

**CERES LW irradiances require elevation correction.**

**CERES LW performs as well as LW from other sources.**

**SYN will be useful where no irradiance measurements!**

# Next steps

## SW irradiances

- correct for terrain and vegetation in validation and modeling
- include spatial variability in forcing data
- develop improved methods for measuring irradiance in alpine environments – snow on radiometer domes

## LW irradiances

- investigate elevation correction

## Both

- investigate relative importance of SW and LW irradiance accuracy
- verify results using additional model(s)